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how to control WIND EROSION

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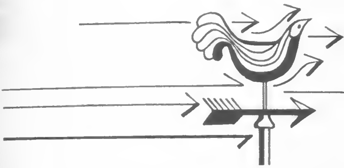

how to control WIND EROSION

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Wind erosion seriously threatens any area of low, variable precipitation, where drought is frequent, and temperatures, evaporation, and windspeeds are high. It is the dominant problem on about 70 million acres of land in the United States—an area that includes 55 million acres of cropland, 9 million acres of rangeland, and 6 million acres of "other" land.

Good farming practices, such as crop rotation and controlled grazing, adequately protect about 34 percent of this land, but specific wind-erosion control is needed on about 46 million acres. Each year about 4.8 million of these acres undergo moderate to severe damage. Wind erosion is most serious in the Great Plains, but it also occurs around the Great Lakes in Michigan, Wisconsin, and Ohio, along the eastern seaboard, in the Southeastern Coastal Areas, and in the Northwest, especially in newly irrigated areas.

The most serious damage from wind erosion is the separation and gradual removal of silt, clay, and organic matter from surface soils. Remaining materials may be sandy and infertile. The sand often piles up in dunes and presents a serious threat to better lands surrounding it. History records that vast agricultural areas in different parts of the world have been seriously damaged this way.

Soil blowing causes other damage. Crops are often damaged or destroyed by the abrasion of windblown soil particles. In the Great Plains Area, wheat, sorghum, cotton, sugar beets, peanuts, and soybeans are affected. Other crops and areas damaged include tomatoes, celery, asparagus, green beans, potatoes, carrots, melons, and other vegetables in Wisconsin, Michigan, Ohio, and New Jersey; and tobacco, corn and other vegetables in the Southeast.

Sugar beets, potatoes, and other vegetables suffer extensive damage on new areas brought under irrigation with pivot mobile overhead sprinklers in the Northwest and in Colorado, Wyoming, Kansas, and Nebraska.

Insects and weed seeds are spread great distances by wind-blown soil. Mounds of windblown soil may smother grass, shrubs, and trees. Drifting soil often buries and ruins fences, hedges, and shelterbelts. Drifted soil and sand sometimes blocks entrances to farmsteads, oil wells, and city homes. Buildings become unfit for living.

During duststorms, traffic tie-ups and accidents are common, air transportation is adversely affected, and electrical switching stations are damaged. Duststorms pollute the atmosphere—as much as 1,290 tons of dust per cubic mile have been measured in the heart of the old dust bowl. This dust is so disagreeable that it is sometimes unbearable for families in the area. Farm animals suffer and may die from dust suffocation.

Necessarily, great care is required to raise crops and livestock, to conserve the soil, and to prevent pollution in these wind-ravaged areas.

PN-1929

Remains of wheat crop after severe wind damage. Wind erosion not only sorts soil material, removing silt, clay, and organic matter, but also sandblasts and destroys crops like wheat and tomatoes.

HOW WIND EROSION OCCURS

Wind erosion is caused by a *strong turbulent wind* blowing across an *unprotected soil surface* that is smooth, *bare, loose, dry,* and *finely granulated.* Soil particles start to move when wind forces overcome gravity. Minimum windspeed required to start movement depends on the size and weight of soil particles and the friction provided by neighboring particles. Where a mixture of single-grained materials is present, the practical windspeed to initiate movement under field conditions is about 13 miles per hour (m.p.h.) at a height of 1 foot.

After soil particles start to move, they are carried by the wind in three types of movement—suspension, saltation, and surface creep. Dust particles less than 0.1 millimeters (mm.) (0.004 inch) in diameter are lifted into the airstream where they float and are carried in *suspension* for many miles before being redeposited.

Coarser particles in the size range from 0.1 to 0.5 mm. (0.004 to 0.02 inch) move in a bouncing or jumping action called *saltation.* They rise almost vertically, rotating at several hundred revolutions per second, travel 10 to 15 times their height of rise, and return to the surface at forward and downward angles of 6 to 12 degrees. When they strike the soil surface, they break down clods and crusts and dislodge more particles.

Most of the dislodged particles in the size range from 0.5 to 1.0 mm. (0.02 to 0.04 inch) roll and move by *surface creep.* Winds of extremely high velocity may move particles larger than 1.0 mm. (0.04 inch), but particles about 0.1 mm. in diameter (0.004 inch) are most erodible.

Soil blowing usually starts on exposed knolls or hilltops, in tracks or paths made by implements or animals, and in corners or turn rows where excessive turning and cultivation have pulverized surface soil. Once blowing begins from these points, the jumping soil particles severely abrade the surface. The *abrasion* breaks down clods, destroys stable crusts, and wears down vegetative residues and living vegetation. Increasing numbers of particles are set in motion as erosion moves downwind. Such increase in soil flow is called *soil avalanching.* Soil flow is zero at the windward edge of an eroding field, but the rate increases leeward until it reaches the maximum that a given wind can carry. The distance downwind at which the maximum rate of flow occurs varies with soil erodibility. The more erodible the soil, the greater the rate of avalanching and the shorter the distance to maximum flow.

PN 1930

Paths of windblown soil grains moving in saltation. The grains move, as shown, in a bouncing, spinning, and jumping manner. When the grains strike the soil surface they break down clods and crusts, and dislodge other erodible particles.

FACTORS AFFECTING WIND EROSION

Major factors that affect the amount of erosion from a given field are soil cloddiness, surface roughness, wind and soil moisture, field length, and vegetative cover. A discussion of each factor follows.

Soil Cloddiness

The cloddiness of a given soil largely indicates whether the wind will erode it. Soil clods prevent wind erosion because they are large enough to resist the forces of the wind and be-

cause they shelter other erodible materials. Clods form during tillage. Their firmness and stability depend on soil moisture, compaction, organic matter, clay content, lime, and microbial activity. Clods are broken down by weathering, tillage, implement and animal traffic, and by abrasion.

Coarse-textured sandy loams, loamy sands, and sands are most susceptible to erosion and breakdown and are least likely to form stable clods. These soils have low silt, clay, and organic-matter content. They form clods only when cultivated while moist and firm. Such clods are readily broken down by rainfall or by freezing and thawing. Fine-textured soils form clods that disintegrate easily after freezing and thawing. The cloddiest and least erodible soils are the loams, silt loams, clay loams, and silty clay loams, especially if they have a 20–to 30–percent clay content and silt ranging from 0.005 to 0.01 mm. (0.0002 to 0.0004 inch) in size.

The size and bulk density of clods, and the proportion of clods to total soil material affect the erodibility of a soil. The proportion of soil aggregates that are more than 0.84 mm. in diameter (the approximate dividing line between erodible and nonerodible sizes) can be used as a simple index of wind erodibility of soils.

This index—called I′—can be obtained for any field soil by dry sieving to determine the percentages of clods greater than 0.84 mm. in diameter, and then referring to available tables. It also can be adjusted to compensate for the increased erosion hazard on slopes and hilltops. Use the index in the wind erosion equation (see p. 4), to determine the amount of cloddiness required to hold wind erosion to a tolerable amount.

Several criteria are commonly used to specify the cloddiness required to control erosion on field soils. One indicates that 50 percent of the soil surface ought to be covered with clods greater than 0.4 inch in diameter. A second indicates half the surface clods ought to be greater than 1.0 mm. (0.04 inch) in diameter, and a third states that two-thirds of the surface soil by weight ought to be of nonerodible size (greater than 0.84 mm. or 0.03 inch in diameter). These criteria are approximate, but soils that meet any one of these criteria usually will resist all but the very strongest winds.

Surface Roughness

In addition to clods and soil aggregates, ridges and depressions formed by tillage also alter windspeed by absorbing and deflecting part of the wind energy away from erodible soil. Rough surfaces also trap saltating particles. This reduces abrasion and the normal buildup of eroding materials downwind.

While the general effect of surface roughness reduces wind erosion, it also increases wind turbulence and exposes smaller areas to greater wind forces. So, too much roughness may substantially reduce the benefits. Optimum roughness for wind ersion is 2 to 5 inches. Roughness, K′, has been evaluated in relation to soil loss and can be used in the wind erosion equation on page 4.

Wind and Soil Moisture

Windspeed and soil moisture both affect wind erosion. For example, the rate of erosion for a 30 mile-per-hour wind is more than three times that for a 20 m.p.h. wind. Wind erosion decreases, however, as soil moisture increases. For example, air-dry soil erodes about one and a third times more than soil with moisture at the approximate wilting point for plants.

For convenience, windspeed and soil moisture are considered together as a local wind erosion climatic factor, known as C′. Values of C′ have been calculated and maps are available giving monthly values for most areas of the United States where wind erosion is a problem.

Field Length

Erosive winds vary highly in direction and seldom follow field boundaries. Therefore, the amount of soil lost from a given field cannot be determined by the width or length of field alone. The distance across the field along the direction of the prevailing wind must be used. Also, if any barrier is present on the windward side of the field, the distance it fully shelters from the wind must be subtracted from the total distance across the field along the prevailing direction.

Prevailing wind-erosion directions and magnitudes are available for 212 locations in the United States. Shelterbelts and barriers pro-

vide variable lengths of shelter, depending on their porosity and shape and on windspeed. A distance equal to 10 times the height of the barrier is usually subtracted from the total distance across a field, when using the wind erosion equation to calculate amount of soil loss.

Vegetative Cover

Good vegetative cover on the land is the most permanent and effective way to control wind erosion. Living or dead vegetative matter protects the soil surface from wind action by reducing windspeed and by preventing much of the direct wind force from reaching erodible soil particles. It also reduces rates of erosion by trapping soil particles, which, in turn, prevents the normal avalanching of soil material downwind.

Protection depends on the quantity and size of residue and how the residue is oriented in relation to prevailing wind direction. The finer the residue, the more it slows the wind and the more it reduces wind erosion. Size is largely determined by kind of residue—wheat stubble is more effective than sorghum or corn stubble, for example. The higher the residue stands above ground, the more it slows the windspeed and lowers the rate of erosion. Effects of quantity, kind, and orientation of vegetative cover on wind erosion can be expressed as single factor, V, the equivalent quantity of vegetative cover. Values for V are available for most crops.

WIND EROSION EQUATION

• The relationship between annual soil loss by wind erosion from a given field and the five factors influencing wind erosion are expressed as $E = f\ (I', K', C', L', V)$.

• E is average annual soil loss in tons per acre.

• I′ is the soil erodibility index indicated by soil aggregates greater than 0.84 mm. in diameter and percentage of land slope.

• C′ is the climatic factor indicated by wind velocity and surface soil moisture.

• K′ is soil surface roughness.

• L′ is unsheltered field width measured along the direction of the prevailing wind.

• V is vegetative cover.

The equation is a highly useful management tool in (1) determining potential wind erosion on any field under existing conditions, and (2) determining conditions of surface roughness, soil cloddiness, vegetative cover, sheltering or width and orientation of field necessary to reduce wind erosion to a tolerable amount.

The equation is used by the Soil Conservation Service, USDA, in designing control practices and advising farmers on conservation programs. Charts, tables, and other supplementary information needed to solve the equation are given in Agriculture Handbook 346, "Wind Erosion Forces in the United States and Their Use in Predicting Soil Loss" and in Special Report 62, "Principles and Methods of Wind-Erosion Control in Iowa."

Agriculture Handbook 346 is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402, at 25 cents a copy. Special Report 62 is available from the Agriculture and Home Economics Experiment Station, Iowa State University, Ames, Iowa 50010. A computer program for solving the equation has also been developed and is available from the ARS Wind Erosion Laboratory, Kansas State University, Manhattan, Kansas 66502.

PRINCIPLES OF CONTROL

Five basic principles of wind-erosion control can be established. They are to—

• Produce, or bring to the soil surface, aggregates or clods large enough to resist the wind force.

• Roughen the land surface to reduce wind velocity and trap drifting soils.

• Reduce field widths along the prevailing wind direction by establishing wind barriers or trap strips at intervals to reduce wind velocity and soil avalanching.

• Establish and maintain vegetation or vegetative residues to protect soil.

• Level or bench land where economically

feasible to reduce effective field widths and erosion rates on slopes and hilltops where converging streamlines of windflow increase increase velocity and wind force.

These principles of control apply everywhere but the usefulness of each varies with local climate, soil, and land-use conditions. For example, it is usually difficult to form stable clods on coarse-textured soils so control of erosion by producing and maintaining clods or by roughening the surface is, at best, temporary. Effective control is much easier on fine-textured soils.

Principles of wind-erosion control can be applied by following a number of practices, some permanent, some temporary. Permanent or continuing practices include stubble mulching, cover crops, stripcropping, crop rotations, shelterbelts, buffer strips, regrassing and reforestation, landforming, and controlled grazing. Temporary methods include emergency tillage to roughen and bring clods to the surface, placement of artificial and earthen barriers, hauled-in mulches, spray-on adhesives, irrigation, and drainage control.

Usually a combination of methods will be most effective and dependable on cultivated lands. For example, when erosion-susceptible crops are grown in sequence with resistant ones, planting in strips in combination with proper residue maintenance may be more effective than either practice alone. Similarly, stripcropping in a small grain-fallow sequence usually combines well with maintaining surface residues.

Some wind erosion may occur under unusually high winds or extreme drought despite the best efforts to control it. However, there is generally much less erosion under extreme conditions when control methods are used than when they are not. In semiarid areas where such conditions periodically prevail, strict control methods should be applied at all times. Avoid excessive cultivation of highly erodible land and maintain vegetative cover whenever possible.

CONTROL ON DRYLAND CULTIVATED SOILS

Practices successfully used to control wind erosion on dryland cultivated soils include stubble mulching and minimum tillage, herbicides, cover crops, stripcropping, crop rotations, wind barriers and shelterbelts, hauled-in mulches, and emergency tillage.

Stubble Mulching and Minimum Tillage

Stubble mulching (management of plant residues for year-round protection of the soil surface) is one of the most effective ways to control wind erosion and conserve soil moisture. The practice, developed in the Great Plains Area, is used mostly with wheat and other small grains and sorghum.

The main purpose of minimum tillage is to grow crops with fewer tillage operations and thus reduce costs of crop production. Minimum tillage also conserves residue, reduces soil pulverization, and holds down soil losses by wind. Developed in the Midwestern Corn Belt, minimum tillage is practiced mainly with row crops.

How much crop residue is needed to control wind erosion? It is impossible to estimate unless all the major factors that affect soil blowing are known. For example, the more susceptible the soil is to movement by wind, the more residue is required to prevent it from blowing. Large-block fields require more residue than narrow fields or fields protected by windbreaks and shelterbelts. Vegetables and other crops that are damaged by abrasion require more residue than do field crops. Arid areas need more residue than humid areas, and regions of high winds require more cover than those of low winds. Because of these varied requirements, it is best to make the necessary measurements and apply the wind erosion equation whenever possible.

If the equation cannot be applied, then practices should be used to conserve the average quantities of residue that have proved effective.

- Table 1 shows the amounts of vegetative cover required to hold wind erosion to 5 tons per acre on fields with different soil textures. These amounts would be needed in an average semiarid region where the climatic factor C′ is about 100 during the windy season.
- Table 2 shows the approximate amounts of vegetative cover required on sandy soils

with about 15 percent nonerodible fractions in the more humid areas. This would be true around the Great Lakes where the climatic factor, C′, is about 18 during the windy season and where the amount of erosion that can be tolerated varies depending on the crop involved.

Considerably more vegetative residue than shown in Tables 1 and 2 must be available after harvest to provide these amounts. Residues are reduced by each tillage operation and by decomposition during fall and winter.

The amount of residue on fields can be determined by sampling, air drying, and weighing, or by visual estimates using photos as guides. The quantity of initial wheat residue can also be estimated by using the grain/straw ratio. On the average this ratio is about 1/100 (one bushel of wheat to each 100 pounds of straw). Weather conditions throughout the growing season, disease, and insects can vary the amount.

Tillage equipment

Tillage machinery and tillage practices can aggravate or alleviate wind erosion. Machines that pulverize the soil or cut down vegetative cover increase soil blowing. If crops are grown, however, weeds must be destroyed and a seedbed prepared. These operations reduce vegetative cover but at the same time can create a cloddy and rough surface to prevent blowing. Farmers should choose implements suited to conditions of a specific area, operate them at medium speeds to avoid pulverizing the soil and reducing residue, and limit tillage operations to as few as are consistent with adequate seedbed preparation and weed control.

Tillage machines used for stubble mulching and minimum tillage are of two types: (1) those that stir and mix the soil, and (2) those that cut beneath the surface without stirring or turning the tilled layer.

Machines that stir and mix the soil.—The *one-way* disk is an excellent implement for destroying weeds and often is the only implement that works in extremely heavy residue. Under average residue and soil conditions, however, it buries too much residue. If used more than once in a tillage sequence, it leaves the soil in a pulverized condition that blows readily.

TABLE 1.—*Pounds of residue required per acre to hold wind erosion to 5 tons per acre annually*

Soil texture [1]	Wheat residue		Sorghum residue		Growing wheat	
	Standing	Flattened	Standing	Flattened	In furrow	On smooth ground
	Pounds per acre	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*
Silts	450	925	1,800	2,600	500	425
Clay and silty clay	800	1,600	3,300	4,750	975	825
Loamy fine sands	1,050	2,125	4,200	6,200	1,200	1,000

[1] Silts with 50 percent nonerodible fractions greater than 0.84 mm. in diameter. Clay and silty clay with 25 percent nonerodible fractions. Loamy fine sand with 10 percent nonerodible fractions.

TABLE 2.—*Pounds of residue required per acre to hold wind erosion to 1 to 5 tons per acre on an average-size field*

Kind of vegetative cover	Residue required to hold wind erosion to:				
	1 ton per acre	2 tons per acre	3 tons per acre	4 tons per acre	5 tons per acre
	Pounds per acre	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*	*Pounds per acre*
Flattened cornstalks	3,850	3,250	2,850	2,500	2,240
Cover crop (growing wheat, rye, or oats)	660	570	510	465	420

Power requirements for the one-way disk on loamy soils with 21-percent clay range from about 1.5 horsepower (hp.) per foot of width with 3-inch-depth tillage to 4.0 hp. per foot with 5-inch-depth tillage. Residue burial increases as depth of tillage is increased. For best conservation, the one-way disk should be operated at a 3- to 4-inch depth, about 3 m.p.h., and at as wide a cutting width (smallest angle in direction of forward travel) consistent with good weed control. Many farmers use the one-way disk only for heavy residues and for initial tillage of stubble land.

The *single, offset, power, and tandem disk harrows* tend to chop and partly bury residue and pulverize and loosen the soil. The offset and tandem disk harrow smooth the surface, break up large clods on plowed land, and de-

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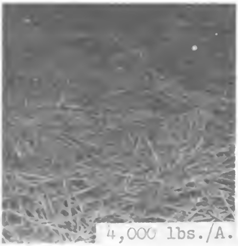

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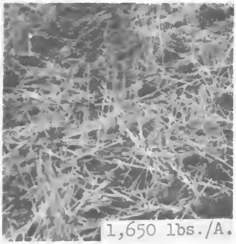

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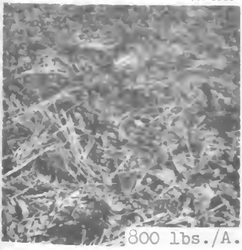

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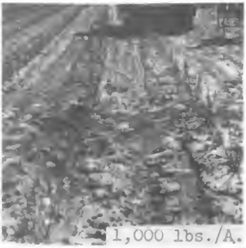

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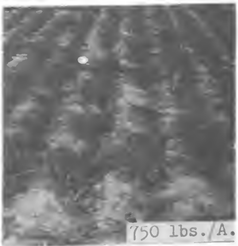

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To determine the amount of residue on fields it is best to sample, air-dry, and weigh vegetative materials, but if that is impractical, then a reasonable visual estimate of the remaining residue can be made by comparing field conditions with the above photographs. The figures in the right-hand corner of the photographs show the amount (pounds of residue per acre) on each field.

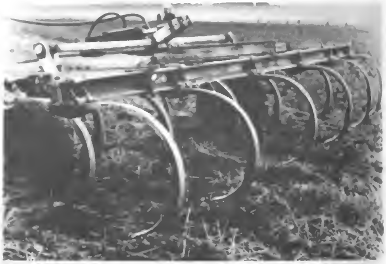
stroy weeds. The smaller, lighter, single disk harrow usually does not kill weeds readily. Repeated operations are often needed, which further pulverize the soil and reduce surface residues. The power disk with gangs of disks driven by the tractor's power takeoff provides intensive tillage action. Considerable soil pulverization and residue burial results, but the machine leaves a rough, undulating surface of depressions and small mounds of soil that partially compensate for residue and clod destruction.

Power requirements for the tandem disk range from about 1.0 to 1.5 hp. per foot of width for 3- and 5-inch-depth tillage, respectively, on loamy soils with 21-percent clay. These disks also should be operated at about 3.5 m.p.h. for best results. Disk harrows should not be used to cultivate bare soils where soil blowing is a hazard.

Field cultivators, sometimes called *duckfoot cultivators,* are reasonably well suited to stubble mulching because they have flexibility of operating depth, tillage point, and spacing between shanks. The tillage points may be narrow sweeps, flat shovels, or double- or single-end narrow shovels. The field cultivator cultivates fallow, prepares the seedbed, and—to a limited extent—roughens and brings clods to the surface to stop soil blowing. It destroys weeds effectively if the residues are not too heavy to prohibit close spacing of the shovel shanks. Power requirements are relatively low except on compacted soils not recently tilled.

Chisel plows are designed for deeper tillage than field cultivators, and they are constructed more rigidly. If residues are not heavy enough to cause clogging, the chisel plow (2-inch-wide tillage points on shanks spaced about 12 inches apart) can be an effective primary stubble-mulch tillage machine. The percentage of residue saved on the surface with the chisel generally decreases with increased amount of residues; it increases with greater height of stubble. The percentage saved ranges from 50 to 80 percent. Most weeds are destroyed and a rough, cloddy surface is produced by close spacing of chisels.

Power requirements for the chisel plow (equipped with 2-inch chisel points spaced 12 inches apart) in loamy soils range from 1.5 to 2.5 hp. per foot of width for 3- and 5-inch depth tillage. The chisel plow has been used ex-



The chisel plow can be used for stubble mulching and for emergency tillage. With chisels spaced 12 inches apart, it leaves about 75 percent of the residue on the surface, destroys weeds, and prepares the soil to absorb water.

tensively for emergency tillage to control wind erosion. Recently, it has become a primary tool for preparing cornland in the more humid Corn Belt Areas.

On cropland where wind erosion is a hazard, the *spring-tooth harrow* is somewhat better than the *spike-tooth harrow.* The spring-tooth harrow penetrates deeper, brings more clods to the surface, causes more ridging, and destroys more small weeds than the spike-tooth harrow. Neither implement can operate in heavy residues. As a rule, other implements are recommended in areas subject to soil blowing.

Mulch treaders are used to distribute and anchor heavy residues and to destroy small weeds just before drilling. Spike-tooth and spade-tooth treaders are available. The spikes or spades curve and the machines operate with the convex portion of the curve forward. Residues are punched into the soil and anchored. Both types of machines have two gangs of spiked wheels operated in tandem and at slight angles to the direction of travel. Power requirements for the spade- and spike-tooth treaders are about 2.4 and 1.9 hp. per foot of width, respectively. These implements are reasonable in cost, require little maintenance, and are easy to operate.

Powered rotary tillers, specifically the *sidewinder tilther,* provide good wind-erosion control for corn grown on sandy soil in Ohio. The tilther is particularly adaptable to row-crop culture and gives intensive tillage to a 12- to 14-inch width of soil for seeding. It leaves the

PN-1940

This rotary tiller provides good wind erosion control for row crops on sandy soils. It provides intensive tillage only to a 12- to 14-inch width for placing seed, and thus leaves the soil and residue between rows undisturbed.

soil and residue between rows undisturbed. Seeding mechanisms may be attached to the machine and tillage and planting done in one operation. If sufficient residue remains between rows, the seedling corn plants are protected from sandblasting. Power requirements for this machine are relatively high—a tractor capable of handling 7 or 8 feet of moldboard plow bottoms is required for a 13-foot rotary tiller. Some clogging occurs in heavy residue.

Machines that cut below the surface—*Subsurface sweeps* and *blades* are the most effective implements available for conserving residues on the soil surface. The implements consist of one or more rigid blades (usually V-shaped but sometimes straight) mounted on a heavy tool bar or frame. The frame may be rigid or flexible to better fit the shape of the land. Blades vary in size from about 30 inches to 7 feet. The implements differ from field cultivators in that blades are wider and the shanks are fewer and longer for better clearance of residue.

Two major disadvantages are (1) inability to kill weeds, particularly grassy species, under moist soil conditions, and (2) failure to bring clods to the surface for erosion protection.

Power requirements are affected by weed growth, soil density, and moisture content. In weed-free soil, the sweeps require less power (about 1.8 hp. per foot of width) than a one-way operated at equal depth. But if there are substantial weed roots more power (about $\frac{1}{2}$ hp. per-foot-width is required for the sweeps than for the one-way. Power requirements also vary depending on kind of frame. Generally, from $\frac{1}{10}$ to 1.5 hp. per foot of width more power is required for the rigid-frame implement than for the flex-frame implement.

Rodweeders destroy weeds, create a firm and smooth seedbed, and maintain residues on the soil surface. They are effective for weed control and final seedbed preparation after initial operations with subsurface sweeps or one-way disks. Their main disadvantages are clogging in heavy residues and a tendency to compact the soil through repeated operation at the same depth. The tendency to form a tillage pan can be alleviated by placing narrow duckfoot shovels or chisel points ahead of the rod to loosen and fracture the soil below the normal tillage depths. When thus equipped, the rodweeder can be used as an effective initial tillage implement. Power requirement for a plain rodweeder without shovels or chisels is about 1.3 hp. per foot of width when operating at a 2-inch depth in loamy soil.

Residue conservation.—All implements described here will bury some surface residue. Speed and depth of operation, angle and concavity of disks, and width, pitch, and angle of sweep blades, are factors that affect residue burial. Height and length of stubble, amount of pretillage residue, and previous positioning or orientation of residue also influence the amount of residue buried. Several investigations indicate that the *average* amount of residue buried by indicated machines is as follows:

PN-1941

The subsurface sweep is the most effective implement available to conserve residues for wind erosion control. It leaves approximately 85 percent of the wheat stubble standing above the surface.

Tillage machine	*Percent of residue reduction by each tillage operation*
Stirring or mixing machines:	
One-way disk (24- to 26-inch disks)	50
One-way disk (18- to 22-inch disks)	40
Tandem or offset disks	50
Power disk	60
Field cultivator (16- to 18-inch sweeps)	20
Chisel plow (2-inch chisels 12 inches apart)	25
Mulch treader (spade-tooth)	25
Mulch treader (spike-tooth)	30
Sidewinder rotary tiller (12 inches tilled on 40-inch center)	30
Subsurface machines:	
Blades (36-inch or wider)	10
Sweeps (24- to 36-inch)	15
Rodweeders—plain rod	10
Rodweeders—with semichisels or shovels	15

These approximate values may be used to estimate the amount of residue remaining at the end of a tillage season. Original residue before tillage can be measured or estimated from the straw/grain ratio. Use the average reduction figures from above and the number of tillage operations (anticipated or conducted) to estimate amount of residue remaining for protection.

Overcoming tillage-machine operating difficulties.—Stubble mulching or minimum tillage operations are sometimes more difficult than clean tillage, mainly because residues clog machines or prevent effective soil stirring for weed control. Such difficulties can be lessened by making careful adjustments, using weights, selecting tillage points, and operating at correct speeds and depths.

Experience also has shown that there are fewer problems when tillage equipment has the following functional and design features:

- Adequate vertical spacing between frame and tillage point—minimum, 18 to 20 inches.
- Adequate horizontal spacing between standards—minimum, 24 inches.
- Effective coulter action—minimum diameter 18 to 20 inches.
- Proper tillage point design—60- to 70-degree, V-angles with 37-degree pitch on subsurface sweeps; 24-inch diameters with 3-inch concavity on disks.
- Correct operation speeds—4 to 5 m.p.h. best for most implements.
- Adequate depth adjustments, preferably with hydraulic controls and depth-gage wheels.
- Adequate disk-angle adjustments.
- Flexible implement frames and widths—5- to 8-foot sections desirable for better performance on uneven land.

A variety of adaptable tillage equipment is also needed to regulate amounts of residue conserved, to control weeds, and to operate under a wide range of soil conditions.

Planting equipment

Proper planting equipment is important in controlling wind erosion. Often the most erosive conditions occur after planting and before the crop is large enough to provide protection. Planting equipment should preserve as much residue as possible, keep the surface rough and cloddy, and at the same time, place seed in moist, firm soil.

Observation and experience indicate that semideep-furrow, single-disk drills, and deep-furrow drills with shovel-, shoe-, or hoe-type openers are most satisfactory for planting small grains in mulch. Deep-furrow drills also provide a roughness in the 2- to 5-inch range, which is most effective for wind-erosion control. Row crops have been most successfully planted in mulch with surface planters equipped with furrow openers, with listers operated at shallow depth, and with till planters.

Drilling and planting problems in mulch can be lessened by using stubble choppers before initial tillage, disk implements during initial and cultivation tillage, mulch treaders after the last tillage operation and before seeding, and rotary straw walker attachments on drills. Small grains will be easier to plant if the drills—

(1) Permit row spacing of 7 to 14 inches, preferably 14 inches for heavy residues.

(2) Have at least 20 inches of clearance between front and rear ranks of openers.

(3) Have at least 17 inches of vertical clearance between frame and bottom of shoe.

(4) Have a shoe width of no more than 6 inches.

(5) Have press wheels that pack seed firmly (closed-type wheels are better than open-type).

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The deep-furrow hoe or shovel drill does an excellent job of planting wheat in residue and providing an effective surface roughness for wind erosion control.

Herbicides

More residue is conserved for wind-erosion control if tillage can be avoided. The ultimate in stubble mulch or minimum tillage is "no tillage" where crops are planted directly into the residue of the previous crop.

As effective chemicals for weed control are developed, no-tillage systems are increasingly used. Herbicides are also being combined with limited tillage to provide better weed control and, at the same time, conserve as much residue as possible for effective wind-erosion control. For example, a system of applying atrazine shortly after wheat harvest—either preceding or following tillage—combined with one-tillage operation just before seeding sorghum the following spring has proved a practical approach to sorghum production in a wheat-sorghum-fallow rotation in west-central Kansas. The herbicide replaces three to five tillage operations between wheat harvest and sorghum establishment, and it reduces production costs and residue destruction.

The effectiveness of herbicides and the techniques for applying them vary with climatic and soil conditions. Because herbicides must be selected for particular crops and locations, and because changes often occur in registered uses of herbicides, you should get specific local recommendations from your county agricultural agent, your State extension weed specialist, or State Experiment Station.

Cover Crops

A cover crop is any crop planted solely to control erosion. It is usually planted for protection when regular crops are off the land, but also may be planted in strips or between rows to provide protection for vegetables or other crops highly susceptible to abrasive injury in the seedling stage. Winter and spring wheat, rye, oats, sorghums, winter peas, and vetch have been used successfully as cover crops.

Cover crops are well suited to the more humid areas around the Great Lakes and in Southeastern United States. They also have a place in parts of the Northern Great Plains where they can trap snow. For example, oats planted in August on summer-fallow land in Montana to be seeded to spring wheat, provided excellent protection from wind erosion and trapped snow which increased soil moisture.

Cover crops are not as practical in the drier areas of the Central and Southern Plains because they compete for moisture. Generally, cover crops are used in this region only for control on erosion-susceptible knolls, on land without protective cover, or on cultivated land to be pastured. In the first two cases, pasturing should be avoided or extremely limited because the aim is to produce vegetative cover for the land. In the third case, overgrazing must be avoided to retain enough residue to protect the land.

Fall-planted oats can be used as winter and spring cover crops in the sugar beet-, potato-, and vegetable-growing areas of Michigan and Wisconsin. They winter-kill, but enough remains to protect the surface. Sugar beets, beans, and some other crops can be planted in the residue, provided a strip for each row is cleared ahead of the planter. Winter wheat and rye also can be used as a cover crop in those areas. Plant the wheat or rye in the fall and allow it to grow through winter and early spring, then spray with a herbicide or cultivate leaving sufficient residue to protect corn and other crop seedlings in late spring.

Winter wheat planted earlier than usual also provides fair to excellent protection from wind erosion. It can be pastured if good precipitation is received in the fall. Early planting, however, is recommended only when other protective residues are depleted and a serious

wind-erosion hazard exists. This is because early planting depletes moisture, protects mites that spread streak mosaic, and increases infections from root-rot organisms. The young wheat also may be damaged by the hessian fly.

Planting sorghum in summer can provide a protective cover for the critical spring-wind period in fields where former crops have not left adequate residue and severe soil blowing is imminent.

Stripcropping

To control wind erosion, crop strips are run straight and at right angles to the prevailing winds. To control water erosion, crop strips follow the contour of the land whenever possible. The relative severity of the two types of erosion determines which way to place the strips. In controlling soil blowing, however, even contour stripcropping is better than planting large areas of a single crop.

Stripcropping does not require any change in cropping practices, and it does not remove any land from cultivation. The field is simply subdivided into alternate strips of erosion-resistant crops and erosion-susceptible crops or fallow. Stripcropping also requires adequate quantities of crop residues as an additional protection against wind erosion.

Erosion-resistant crops include small grains and other crops seeded closely to cover the ground rapidly. Erosion-susceptible crops are cotton, tobacco, sugar beets, peas, beans, potatoes, peanuts, asparagus, and most truck crops. Corn and sorghum are intermediate in resistance to wind erosion.

Stripcropping controls soil blowing by reducing soil avalanching. The rate of soil avalanching varies directly with the erodibility of the soil and the width of the eroding field. So one factor that determines the width of the strips is the kind of soil. Another is land use. In the vegetable-growing areas in the Great Lakes Region, for example, buffer strips consisting of very narrow strips of rye, wheat, or grass are used with wider strips of erosion-susceptible land. A common practice is to make the buffers one-tenth as wide as the erosion-susceptible strips. For example, buffers would be 8 feet wide if erosion-susceptible strips are 80 feet wide. In the drier wheat and sorghum areas of the Great Plains, erosion-resistant and erosion-susceptible strips are generally equal in width.

Average widths on different soil textures in the Central Great Plains are:

Soil	*Width of strips* (feet)
Sand	20
Loamy sand	25
Granulated clay	80
Sandy loam	100
Silty clay	150
Loam	250
Silt loam	280
Clay loam	350
Silty clay loam	430

Topographic features, such as irregularity, length, degree, and exposure of slope in relation to prevailing winds, influence the effectiveness of crop strips. The design for a stripcropping system depends on these features and on the type of soil.

Standard farm machinery does not work efficiently on strips narrower than 50 feet. On fields that require strips narrower than 50 feet, consider growing erosion-resistant crops continuously or seeding the field to a permanent cover.

Crop Rotations

A system of crop rotations is commonly used on dryland subject to soil blowing. Two or more crops or one crop and fallow are alternated in a regular sequence on a given area.

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A stripcropping sequence of wheat and fallow is effective in controlling wind erosion. Width of strip required for control varies with soil texture. Widths for nine different textures are given in this bulletin.

Common rotations include wheat and fallow, wheat-wheat-fallow, wheat-sorghum-fallow, and cotton-sorghum. In some areas, where there is enough moisture, legumes and grasses are also planted in the rotations. Crop rotations—especially those that include legumes and grasses—often improve soil tilth and productivity, but their major function is to provide year-round cover that prevents soil blowing.

Wind Barriers and Shelterbelts

Wind barriers and shelterbelts affect wind erosion in two ways. First, they lower windspeed in their lee enough to keep the soil from moving. Second, they reduce field length and, consequently, soil avalanching. Plantings of trees and shrubs in one to 10 rows, field crops in narrow rows, snow fences, solid wooden or rock walls, and earthen banks—all have been used as wind barriers.

The effectiveness of any barrier depends on the wind velocity and direction, and on the shape, width, and porosity of the barrier. When the wind blows at right angles to the average tree shelterbelt, wind velocity is reduced 70 to 80 percent near the belt. Velocity is reduced by 20 percent at a distance equal to 20 times the height of the belt. But no reduction in velocity occurs at a distance equal to 30 to 40 times the belt heights (leeward of the belt). The higher the average wind velocity, the closer shelterbelts or other barriers should be spaced to protect soil from blowing. If the wind velocity is 40 m.p.h. at a 50-foot height, the following distances will be protected from soil erosion by the barriers indicated.

Windbreak	*Factors for determining protected distances* [1]
Trees and shrubs:	
2-row (mulberry)	18.2
5-row (plum, cedar, mulberry, elm, olive)	15.0
1-row (Osage orange)	12.0
3-row (cedar (2), shrub)	11.0
1-row (Siberian elm)	9.5
Annual crops:	
Kochia	12.0
Sudangrass	7.5
Grain sorghum	6.0
Forage sorghum	4.0
Broomcorn	1.0

[1] To find the distance protected by your particular barrier, multiply your barrier's height by the appropriate number in the right-hand column.

The relatively short distances protected by wind barriers limit them as a method for complete wind-erosion control. The close spacing required and the variability in wind direction make it necessary to surround fields with barriers. This reduces field size and is objectionable where large equipment or mobile irrigation systems are used. For this reason, tree shelterbelts are usually planted at 80-rod intervals along field boundaries, at 350- to 450-foot intervals on highly erosive soils, or at 500- to 650-foot intervals on moderately erosive soils.

Other wind-erosion control practices, such as stubble mulching, are then applied to the land in combination with the windbreaks. Annual crop and grass barriers are also generally planted at wider intervals than required for full protection. For example, one or two rows of sorghum or grass planted at 60-foot intervals is a common supplement to other wind-erosion control measures.

Shelterbelts planted in the 1930's were generally wide—consisting of 10 to 12 rows. Experience and research indicate, however, that narrower belts of medium porosity are equally or more effective and take less land out of production.

The ideal is a one-row belt, and in the more humid areas of Wisconsin, Michigan, New Jersey, and Ohio, single rows of willow, privet, red or white pine, or Norway spruce make effective barriers. When trees die in the row in the more arid areas of the Great Plains, three rows should be planted to insure protection. Generally, the belts should consist of a shrub, a conifer, and a fast-growing deciduous tree. Fast-growing trees suggested for three-row belts in the Central Plains include caragana, tamarisk, plum, honeysuckle, and sumac shrubs; Siberian elm, honeylocust, and Plains cottonwood; and redcedar or Virginia and Ponderosa pine conifers.

In the Northern Plains, single-row shelterbelts should be used when snow trapping and spreading is the main objective, but two- to three-row moderately dense belts are recommended for wind-erosion control. Species suitable for the Northern Plains include buffaloberry, caragana, honeysuckle, plum, and sumac shrubs; Ponderosa and limber pines, redcedar, and Rocky Mountain juniper conifers; and Siberian elm, ash, and oak deciduous trees.

Tree shelterbelts have only limited application in the Southern Plains. Annual crop or grass barriers work better there. If trees and shrubs are planted in the Southern Plains, consider Arizona cypress, Siberian elm, redcedar, oak, oriental arborvitae, and tamarisk.

Nearly any plant that reaches substantial height and retains its lower leaves can be used as an annual crop or grass barrier. Suggested plants include pampas, bamboo, tall wheat, and plains bristlegrass; hybrid forage sorghum (varieties such as Cropguard and Yieldbuilder), kenaf, corn, and sunflower annual crops.

Artificial barriers (snow fencing, board walls, and earthen banks) provide temporary protection for highly erodible areas such as livestock watering sites and traffic lanes. They also protect high-value crops, and can help stabilize dune or sand-drift areas. Generally, artificial barriers provide relatively short zones of protection (4-foot snow fencing protects about 40 feet, and 2-foot earthen banks about 30 feet) and they are costly to construct. So their application to wind-erosion control in dryland agriculture is limited.

Hauled-in Mulches

Hauled-in mulches are only of limited value in controlling wind erosion on dryland agriculture. Their principal use in dryland farming is to treat highly erosive knolls and blowouts, particularly in sandy soils. Cotton gin trash, straw, manure, native hay, and corncobs are used as mulches.

Use 1 to 2 tons of straw or hay, 4 to 5 tons of corncobs, 6 to 8 tons of manure, or about 5 tons of cotton gin trash per acre to effectively control erosion on vulnerable spots and prevent their spreading to other parts of the field. Materials may be spread by hand or with a manure spreader. They should be anchored with a disk packer or ordinary disk operated at a very small angle so disks do not bury residue.

Emergency Tillage

Once vegetative cover is depleted, emergency tillage will be necessary. Emergency tillage, however, should be used only after such methods as stubble mulching, cover crops, stripcropping, crop rotations, regular tillage, and windbreaks and other barriers have failed. Emergency tillage helps create a rough, cloddy soil surface to resist the force of the wind. It is only a temporary measure because clods readily disintegrate.

Use emergency tillage before soil blowing starts rather than after. Soil erodes more rapidly under abrasion of moving soil particles and requires more drastic measures to prevent it from further erosion. If soil blowing has started, begin emergency tillage on the windward edge of the field.

Measures for soil types

Sandy soils are by far the most difficult to hold with emergency tillage. Few clods are obtained, regardless of the depth tilled or tool used. At best, any emergency measure in sand will be rather short-lived; it is far better to keep such soils permanently covered with vegetation. If tillage is required, work the entire area with a lister at sufficient depth to produce a rough surface. As soon as possible, farmers should allow a natural vegetative cover to take over and discontinue tilling. There is more danger of erosion from too much tillage of sandy soils than from no tillage.

Fine- and medium-textured soils respond more readily to emergency tillage than sand. Use chisels to produce a rough, cloddy surface. Chisel the entire field rather than at intervals across the field.

Tillage practices

Effective implements for emergency tillage are: listers with 8- or 14-inch bottoms, narrow and heavy-duty chisels, duckfoot and widespade shovel cultivators, one-ways with two or three disks removed at intervals to give a lister effect, the "sand fighter," and pitting machines. The choice of implement and the method used depends on the seriousness of possible erosion, soil texture, and the cropping system.

Emergency tillage must be at right angles to prevailing winds. Till deep enough to bring compact clods to the surface—usually 3 to 6 inches. If serious soil blowing is expected, till not only on individual fields but on large areas as well. Use a 14-inch lister with 42-inch spacing or an 8-inch lister spaced 20 to 24 inches. If moderate soil blowing is expected, till individual fields with chisels or cultivators. For most types of chisels, a 24-inch spacing gives good protection. Intermediate speeds of culti-

vation—3.5 to 4.0 m.p.h.—provide the most effective surfaces.

A crop also indicates the choice of emergency tillage methods. Often a wheat crop may be too sparse to hold against erosive winds, yet a partial crop may be salvaged. In such cases, till the entire field with a chisel with the points spaced 54 inches apart.

Deep Plowing

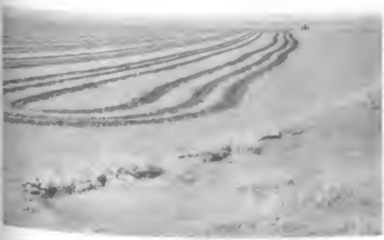
Deep plowing provides wind-erosion control on sandy soils if adequate amounts of clod-forming clay subsoil can be brought to the surface. This is done with large moldboard or disk plows to a depth of about 16 to 48 inches. Experiences in Oklahoma, Kansas, and Texas show deep plowing increases clay from 4 to 12 percent; but a reachable layer with a clay content of at least 27 percent is necessary for the practice to be effective. Generally, the increased cloddiness and roughness that results from deep plowing of sandy soils is only temporary. Therefore, the practice must be supplemented with other wind-erosion control measures.

Landforming and Benching

Land generally is modified for irrigation, water-erosion control, and moisture conservation. Sometimes this land modification changes exposed knolls, tops and slopes of hills, and field lengths that affect the rate and amount of erosion of soil by wind.

Research data on the effect of land modification on wind erosion are meager, but calculations using the wind erosion equation for average Great Plains climatic, soil, and residue conditions indicate that shortening field lengths from 1,000 to 100 feet could reduce potential soil loss 50 percent. Other calculations where a 1,200-foot-long, 4-percent slope is benched with a series of 240-foot-wide level benches show the effect could reduce soil loss from wind erosion 60 percent.

While it seems unlikely that land will be extensively modified to control wind erosion, all indications are that it will be increasingly modified for irrigation and to control water erosion. These same land modifications also may provide substantial wind-erosion control.



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Effective emergency tillage for wind erosion control can be accomplished by listing (top left), chiseling (bottom left), or using the "sand fighter" (above), an implement that provides a cloddy soil surface resistant to wind forces.

CONTROL ON IRRIGATED LANDS

Wind erosion occurs on irrigated land because (1) a high percentage of the crops grown are row crops that are harvested and leave very little or no residue, and (2) land leveling and other intensive soil working while land is prepared for irrigation may pulverize the soil and destroy all vegetation.

Wind-erosion control on irrigated land can be attained by applying most of the control measures practiced on drylands. Some special procedures, however, are used depending on whether the land is a new or an established irrigated field.

Control on New Fields

Initial development

First, decide how much new land can be properly handled. Do not destroy native vegetative cover on an area being developed for irrigation unless it can be properly prepared and handled.

Start leveling and ditching during the growing season when wind velocities are usually low and a cover crop can be established if needed. Conduct "shakedown" tests of the irrigation system and correct any high or low spots in the field or other defects.

If wind erosion is a threat, plant a winter-hardy small grain in August as the first crop. This crop is more often used to tie down the soil than to reap a harvest. Start regular cropping practices the following year if the soil is not highly susceptible to blowing. If it is highly susceptible, keep the field under cover crop the entire season or plant pasture.

Control on Established Fields

Tillage and planting tips

The time between seedbed preparation and planting should be as short as possible. Delay tilling old residue and allow only enough time to get the summer crop planted at the proper date.

Avoid pulverizing the soil by overworking it. Do all plowing, ridging, disking, or other tillage when soil is moist enough to produce clods but not wet enough to cause compaction. Vary depths to find clods. If soil is so dry that deep tillage will not bring clods, apply irrigation water before tilling. Do not destroy ridges unnecessarily.

When preparing a seedbed for hay or pasture crops do not plow residue. Plant directly into untilled residue or, if tillage is needed to kill weeds or volunteer growth, use subsurface sweeps.

Plant row crops, such as corn, beans, sugar beets, and soybeans, on ridges that have rough, cloddy surfaces. The ridges will control wind erosion, will shelter seedlings, and will provide furrows for irrigation. Conventional planters can be adapted to ridge planting by attaching shovels in front of planters.

Use chisels, listers, and other implements suggested for dryland farming to provide rough, cloddy surfaces. Make ridges at right angles to prevailing winds.

Provide cover

If there is no residue from the previous crop, plant a cover crop to protect the land during winter and early spring. Winter wheat, rye, vetch, or oats provide effective covers in adapted areas.

On large fields, reduce field length by leaving disk or other tillage-machine-width strips of stubble or cover crop when preparing seedbeds. After the crop produces sufficient growth for protection, the strips can be tilled for weed control. Strips should be about 100 feet apart on soils that blow easily.

Use hauled-in mulches of straw or hay on small, highly erosive spots. To avoid volunteer growth, try to find and use material that does not contain excessive seed.

Use shelterbelts and barriers

Tree windbreaks may be used to protect farmsteads and gardens on irrigated lands. They are not recommended for irrigated fields because they use water and take valuable land out of production. One of several *annual crop* or *grass barriers* listed for dryland agriculture can be used on fields (see p. 12). Plant at 60 to 100 foot intervals.

Use irrigation

Generally, irrigating to prevent soil blowing is considered impractical and wasteful of water. The only time irrigation should be used

to control wind erosion is to save a high-value crop that is being severely damaged.

Pivot Sprinkler Irrigation Systems

Mobile sprinkler irrigation systems that pivot about the well are now installed on a large enough scale to merit special consideration. Some serious wind-erosion problems have developed on sandy soils during winter and early spring after harvest of potato and sugar beet crops.

While most wind-erosion control practices prescribed for other irrigated lands can be used on this land, there are some specific problems. For example, wind barriers that grow to substantial heights cannot be used because they interfere with movement of the sprinkler-head water-supply pipe. Annual crop barriers of sorghum or corn, grass, short-growing shrubs such as plum or honeysuckle, and perhaps earthen banks could be used. However, the best methods of controlling wind erosion on sandy lands appear to be cover crops, minimum and stubble-mulch tillage, crop rotations, stripcropping, or buffers.

Cover crops of rye, wheat, barley, or oats will provide effective control, especially after early crops of potatoes. Adequate fertilizer should be applied to the cover crop. If the season is dry, the crop should be irrigated to insure rapid germination and growth. Minimum and stubble-mulch tillage can be used in planting potatoes after small grains or corn, or wheat after potatoes or small grains. This practice may not be practical for sugar beets because the residue may interfere with electric-eye beet thinners.

Crop rotations should include small grains in alternate years, plus a stubble mulching program on the small grain to retain as much residue as possible to protect the land during the potato or beet year. Another choice is to plant the potatoes or beets directly into untilled stubble.

Where stripcropping is used, the problem is to find two crops with compatible irrigation timing and water requirements. Probably corn or sorghum and potatoes or beets would be most compatible. Strips should be the widths recommended for the particular soil texture under dryland agriculture (see p. 12). However, if corn or sorghum is used, strips could be slightly wider because of the barrier effect provided by the tall corn. An additional width equal to 10 times the effective height of the corn or sorghum is suggested. Example: If corn is 10 feet high the strip could be an additional 100 feet in width.

In the potato or beet year, a corn-potato or corn-beet rotation tillage can leave narrow buffers of standing or semi-standing corn (harvested) to provide protection for the potatoes or beets immediately after planting. Four rows of corn should be wide enough for a buffer.

On extremely sandy soils in semiarid regions, the wind erosion equation will probably indicate that strips between buffers will be 20 feet wide or less. If this is objectionable because of interference with wide machinery, strips 40 feet wide with buffers perpendicular to prevailing wind direction probably would provide adequate protection for all but the strongest winds.

CONTROL ON VEGETABLE AND SPECIALTY CROPLANDS

Numerous vegetable and other specialty crops are damaged by moving soil particles, burial of plants, removal of soil from roots, and by the drying and twisting effects of wind on the plants. The problem is most severe on mineral soils, but also occurs on organic mucks.

Erosion tolerance for most vegetables is extremely low. Beets, carrots, onions, spinach, and squash are damaged by soil movement of $\frac{1}{10}$ to $\frac{1}{2}$ ton per acre. Potatoes, asparagus, broccoli, cabbage, and eggplant will tolerate up to 1.0 ton per acre of soil blowing and sweet corn and peanuts will not suffer severe damage with soil losses up to 2.0 tons per acre.

Damage to such crops generally occurs in the spring when the plants are very small. It may occur in only a few minutes or over several hours. The critical period of exposure is relatively short—usually 2 or 3 weeks. The wind-erosion control system, therefore, must be designed to provide effective short-term protection.

Most of the wind-erosion control practices used for dryland agriculture also apply to vegetable and specialty crops. However, the

method of use and design may be slightly different.

Buffer Strips and Annual Crop Rows

Buffer strips have proved effective for wind-erosion control of the crops listed in the States indicated below.

Where single row cereal buffers are used to protect carrots, onions, or beets, the best practice is to seed the buffer with the vegetable. After the critical blow season is past, get rid of the buffers by cultivation or with chemicals. To avoid difficulty and expense in removal, do this before the buffers reach 10 inches in height.

Cover Crops

Planting a cover crop is an effective way to control wind erosion on vegetable land through winter and early spring. Rye, wheat, and oats can be used in the vegetable-growing areas of Michigan, Wisconsin, Ohio, New Jersey, and Connecticut. Barley and flax have produced effective covers in the Red River Valley of North Dakota. Oats are generally used in Illinois. Annual ryegrass can sometimes be used in Michigan and Ohio. Oats offer an advantage over winter-hardy crops because by freezing they use less soil water and leave a protective residue on the soil. Loss of soil moisture to other kinds of crops can be reduced by clipping or by killing the crops with chemicals.

An effective practice for wind-erosion control of onions grown on the muck soils of Michigan is to seed oats at 2 bushels per acre in the fall. Mix enough rye with the oats to produce a plant every 3 or 4 square feet. The onion crop is planted in the spring without seedbed preparation. The oats have winter-killed, but enough rye plants remain to control wind erosion.

Shelterbelts and Barriers

Tree shelterbelts can provide longtime protection for vegetable fields. Generally, two rows of tall-growing adapted evergreens or deciduous trees should be planted around farm boundaries. Then single rows of the trees can be used at 40-rod intervals. Kinds of trees for this purpose include pine, redcedar, spruce, Siberian elm, mulberry, ash, maple, and poplar. Privet, purple willow, multiflora rose, and other adapted species of shrub also provide effective protection for vegetable crops. Space them at intervals of about 300 feet on most sandy soils. Objections to tree and shrub windbreaks are that they compete with the crop for water and plant nutrients, and that the roots may clog drain tiles.

Solid board fences, snow fence, burlap fences, crate walls, and earthen banks also can be used to protect vegetable crops. Fences should be 3 to 5 feet high and spaced at intervals of about 15 times their height. Earthen banks should be 2 feet high and spaced at 12 to 15 times their height. The high cost of earthen banks limits their use to small fields and high-value crops.

Spray-on Adhesives

Several spray-on adhesives of petroleum, chemical, and organic origin are available for temporary wind-erosion control of vegetable seedlings on mineral soils. Tests to date indicate that they are not effective on muck soils because of physical and chemical reactions.

Some of the adhesives are relatively expensive, but a few are economical to use on high-value crops threatened by serious blowing that cannot be controlled by other methods. A list of materials that control effectively at reasonable cost follows on page 19.

Kind of buffer	*Width of strip*	*Crop protected*	*Location*
Rye	1 drill row	2 rows of beets, carrots	Michigan
Rye	4 feet	20 feet of melons	Michigan
Rye or wheat	7 to 8 feet	70 feet to 80 feet of potatoes, beets	Michigan
Barley or spring rye	1 drill row	3 rows of onions	Michigan (mucks)
Grain sorghum	4 rows	8 to 10 rows of peanuts	Texas
Corn	4 rows	16 rows of tomatoes	Texas
Rye	10 feet	4 rows of peanuts	Florida
Rye	1 to 2 feet	30 feet of tomatoes	South Carolina
Rye	6 feet	60 feet of melons	New Jersey

Stabilizer	*Water dilution*	*Type of nozzle*	*Application rate* (Gallons per acre)	*Cost of concentrate per acre*
Anionic asphalt emulsion	7:1	coarse-spray	1,200	$53
Latex emulsion	12.5:1	fine-spray	235	$24
Resin-in-water emulsion	4:1	fine-spray	300	$12
Liquid protein colloid	10:1	fine-spray	440	$10
Fermented corn extract	10:1	fine-spray	570	$10

When applied as a preemergent spray, the adhesives should provide protection until the crop has established an adequate canopy. A herbicide must be applied with the stabilizing material because any mechanical stirring of the soil to destroy weeds would also reduce the effectiveness of the stabilizers.

Miscellaneous Control Measures

Irrigation, use of heavy rollers, and maintaining high water tables will provide some protection from soil blowing in areas where these controls can be applied. Irrigating vegetables to control wind erosion is expensive, and often difficult to justify. However, if a sprinkler system is available, you can irrigate highly erodible spots in fields to protect tender crops and prevent spread to other parts of the field.

Compaction with a roller is an effective method of reducing wind erosion of muck soils. Rollers pack the fluffy lightweight soil material together and smooth the land so wind forces cannot attack the particles to initiate movement. The roller should apply from 600 to 800 pounds per linear foot of pressure to the soil.

Maintaining high water tables is a possibility in areas that are tile drained. High water tables are best used with muck soils, particularly in areas where wind erosion problems develop on land bared by sod-farming enterprises. Simply block the tile outlet to allow the water table to rise.

PN-1947

Temporary wind erosion control is provided by a spray-on adhesive emulsion. Here, the emulsion is applied to vegetable seedlings on a mineral soil.

CONTROL ON GRAZING LANDS

Wind erosion occurs on overgrazed lands and around water sites, saltboxes, lanes, and shaded spots where animal traffic concentrates. The problem is found on both native grass rangeland in arid and semiarid regions and on winter-wheat land that is pastured in the Great Plains.

Control on grazing lands can be attained by:

- Limiting livestock numbers on any given area.
- Providing reserves of harvested forage to feed during drought periods.
- Dividing pastures and using rotational grazing.
- Supplying several watering and saltbox sites and moving the boxes from time to time.
- Fencing animals away from highly erosive spots.
- Avoiding gates or lanes on erosive sites and moving them if an erosion problem develops.
- Providing wind barriers to protect permanent water sites and lanes.
- Applying hauled-in mulches, brush, and automobile tires to blowout spots caused by heavy traffic, utility pole, or gas line installations.

The increased vegetation resulting from any

crop improvement practice also helps to control wind erosion. Practices that have proved beneficial are: contour furrowing or pitting to reduce runoff and conserve moisture, interseeding of more productive species of grass, spraying to control weeds and brush, and applying commercial fertilizers when economically feasible.

CONTROL ON SAND DUNES AND OTHER PROBLEM AREAS

Stabilization of sand dunes and stabilization of slag dumps and slime ponds from mining operations are sufficiently important to warrant special consideration. Reclamation methods for these problem areas often are determined by economics, but the goal in all cases is to establish permanent vegetation.

The sand-dune problem develops mostly along coastal areas and affects summer beach cottages, military installations, and highways. Drifting also can be an agricultural problem on sandy rangeland along rivers. The beach cottage-highway-military situation can be treated with costly quick-control measures, but sand drift on rangelands must be treated more slowly and economically.

Slag dumps and slime ponds usually are connected with copper and lead mining operations. Because air pollution from the mines is a health hazard, mine dumps generally are reclaimed by more costly methods.

Stabilization of sand dunes affecting summer homes, military bases, and highways may be accomplished by one or a combination of the following methods:

(1) Bulldoze off dune crests to reduce areas exposed to maximum winds and begin stabilizing the side facing prevailing winds.

(2) Use sand fences to trap and hold moving material. Install fences perpendicularly to prevailing winds. Severe cases may require paddocks—sometimes as small as 25 by 25 feet. Snow fencing, plastic netting, dried grass or reeds, or stabilized sand dikes can be used. Fences should be 4 to 5 feet high and placed about 300 feet apart. Undercutting can be avoided if about 1 foot of backfill is placed along the fence base. Sand dikes should be 1.5 feet high and spaced no more than 100 feet apart.

(3) Use crushed rock, stones, gravel, or shale blankets. To provide adequate protection, you will need 20 tons per acre of fine gravel, 50 tons of medium gravel or crushed stone, or 100 tons of coarse crushed rock or shale.

(4) Use hay or straw mulches at the rate of 2 to 3 tons per acre. Anchor with disk harrows, disk packers, or asphalt adhesives. Use blower-type mulch spreader or beater-type manure spreader to apply mulch.

(5) Apply brush, chicken wire, or snow fence flat to the surface on highly erosive spots. Anchor the wire with stakes.

(6) Use petroleum and chemical spray-on adhesives. Resin-in-water emulsions (Coherex), asphalt emulsions, cutback asphalt, and oil/latex emulsions (Unisol) —all are effective. Apply concentrated Coherex and asphalt products at the rate of 1/4 gallon per square yard or 1,200 gallons per acre. Apply Unisol at 1,200 gallons per acre.

(7) Test the sand and determine nutrient requirements. Applications of up to 500 pounds per acre of 16–20–0 fertilizer have been required on some dune sands to establish vegetation.

(8) Plant seeds or culms of adapted grasses preferably with mulch, adhesive, or other protection. Effective grasses—

PN 1948

Sand dunes on coasts and lake beaches cause serious problems near summer cottages, and on highways and military installations. Control can be maintained in these locations through the planting of beachgrass, the use of sand fences, and the application of hay mulches that contain an asphaltic adhesive.

where they will grow—include American and European beach, Australian veldt, star, weeping love, pampas, marram, bamboo, and perennial rye. Irrigate the seeds or culms, if possible. When planting beach grasses, place 3 to 5 culms per hill, spaced 18 inches apart. Consult local Soil Conservation Service or Extension Service personnel for grass species adapted to specific areas.

(9) Plant adapted trees and shrubs on some dune areas. For example, pine Christmas trees can be grown on beach sands around Lake Michigan. Sandplum, snowberry, and honeysuckle have been successfully established in drier areas. Consult local specialists for recommended species for other areas.

Methods of stabilizing slag dumps and slime ponds are similar to those used for sand dunes. You can—

(1) Use sand fences and other artificial wind barriers to still sifting fine material. It is futile to attempt to establish growth in moving sands.
(2) Add agricultural lime to correct the pH of the material. Leaching makes frequent applications more effective than heavy applications.
(3) Use crushed rock or shale blankets, straw and hay mulches, and petroleum and chemical adhesives where applicable. Rates should be the same as for stabilizing sand dunes.
(4) Test the materials and determine nutrient requirements. Application of 5-13-5 fertilizers at 600 pounds per acre have adequately met requirements in some areas. Further applications are required until plants drop leaves and create their own humus.
(5) Plant seeds or culms of adapted grasses, trees, and shrubs, preferably in combination with a mulch. Grasses that have been effective include star, kweek, weeping love, marram, pampas, pygras, bamboo, bermuda, and johnson-grass. Check with local specialists about recommendations for these and other grasses, trees, and shrubs.

A low-cost method of stabilizing dunes on low-value, sandy rangelands includes:

(1) Excluding livestock completely.
(2) Stimulating growth of existing vegetation (it is more suitable than introduced species) by applying fertilizer in bare dune interfaces on successive years. Test the sand to determine nutrient needs; however, 300 pounds per acre of 6-12-6 has met requirements in some areas.
(3) Beginning stabilization operations on windward side of dune area and working through the dunes in successive years.
(4) Refertilizing as necessary for vigorous growth. If fertilization alone will not stimulate native grasses and stabilize a particular area, seed or plant sand-binding grasses and use mulches and fertilizers as recommended for beach sand dunes and mine-slag piles and ponds.

Manage stabilized sand dune and mine dump land carefully. Cover trails and roads leading through loose sand with nonerodible material such as gravel, macadam, or concrete. When building homes, mulch and establish vegetation on the area surrounding the construction site as soon as possible. Guard grasslands, woodlands, or scrublands from fire, overgrazing, or excessive tree cutting. Use stabilized dunes mostly for recreational purposes and for limited pasture or woodland.

PRECAUTIONS

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide

sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or an endorsement over products not mentioned.

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